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7. Abstract

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This report discusses the geology of the area in the vicinity of the 100-K Area at the Hanford Site of south-central Washington. The study includes data from recently drilled boreholes, as well as older boreholes. It includes an isopach map of the Hanford fm, contour map of the upper Ringold Formation surface, and five geologic cross-sections. Subsurface hydrologic units are compared to local stratigraphy.

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1.0 INTRODUCTION

The purpose of this report is to discuss the geologic setting of the 100-K Area and vicinity. This discussion is based on data acquired during recent drilling activities, data from older projects and boreholes from the area, and analysis of analogous geologic units from outcrops and coreholes located elsewhere in the region. The report is divided into two parts: (1) a brief review of the regional setting (taken largely from Lindsey and Jaeger, 1993) and (2) a detailed discussion of 100-K Area geology.

2.0 REGIONAL GEOGRAPHIC AND GEOLOGIC SETTING

2.1 GEOGRAPHY AND PHYSIOGRAPHY

The Hanford Site is situated within the Pasco Basin of south-central Washington (Figure 1). The Pasco Basin is one of numerous topographic basins located within the Columbia Intermontane Province, a broad depression located between the Cascade Range on the west and the Rocky Mountains on the east (Figure 2) (Freeman et al. 1945; Thornbury 1965). The Pasco Basin is bounded on the north by the Saddle Mountains, on the west by Hog Ranch-Naneum Ridge uplift, on the south by the Rattlesnake Hills and Rattlesnake Mountain, and on the east by the Palouse Slope (Figures 1 and 3).

The physiography of the Hanford Site is dominated by the low-relief plains of the Central Plains physiographic region and the ridges of the Yakima Folds physiographic region. Surface topography at the Hanford Site is the result of:

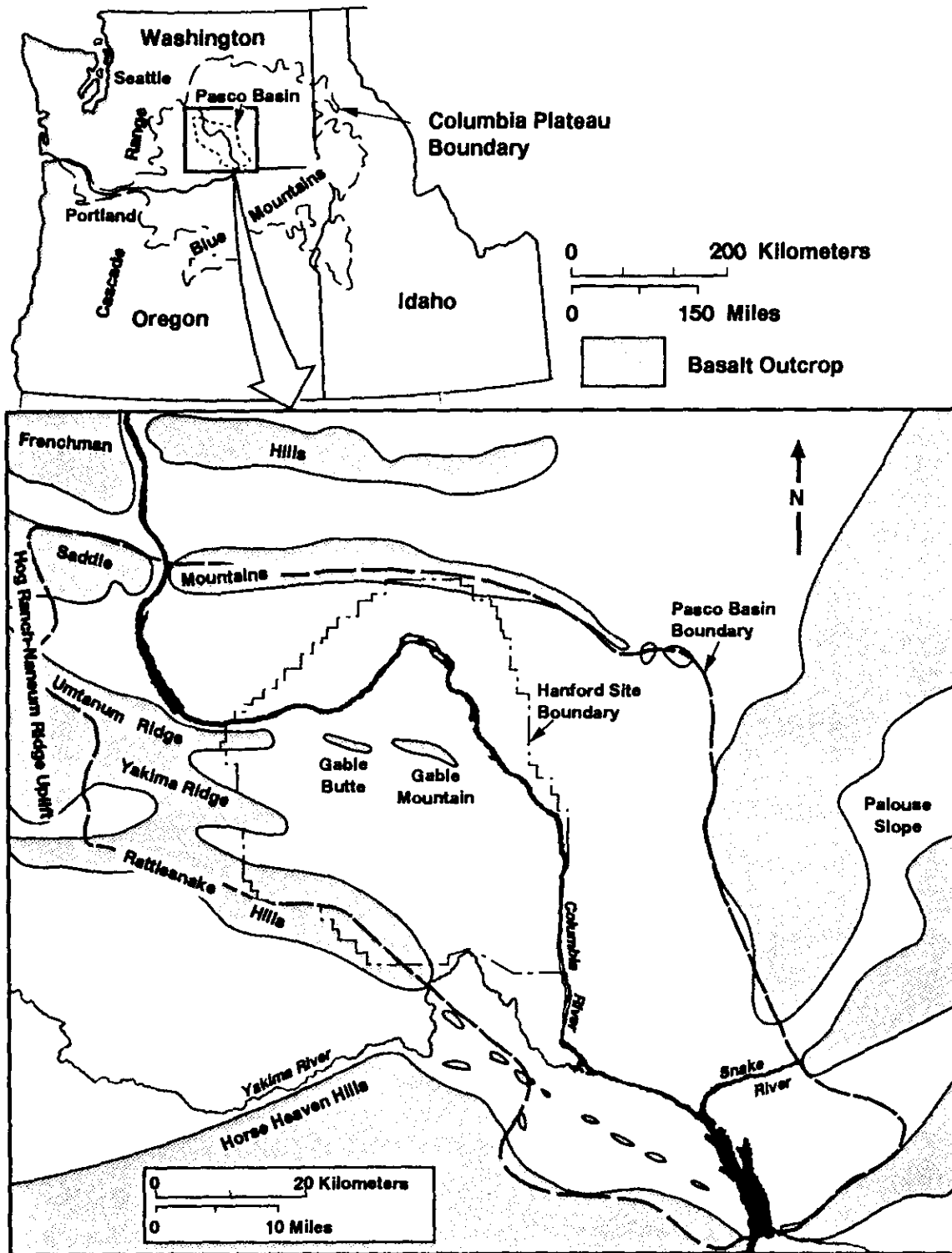
- Uplift of anticlinal ridges
- Deposition and erosion by Pleistocene cataclysmic flooding
- Holocene eolian and alluvial activity
- Landsliding.

The 100-K Area is situated in the northern part of the Hanford Site on the south side of the Columbia River near an area commonly called the "Horn." Surface topography in the area of the "Horn" is the product of cataclysmic flood deposition and erosion, post-flood eolian activity, and post-flood erosion and deposition associated with the Columbia River. More detailed discussion of site physiography can be found in DOE (1988).

2.2 GEOLOGY

The Pasco Basin and the Hanford Site is underlain by Miocene-aged basalts of the Columbia River Basalt Group (Myers et al. 1979; Reidel and Fecht 1981; DOE 1988; Tolan et al. 1989; Reidel et al. 1992), the interbedded sediments of the Ellensburg Formation (Reidel and Fecht 1981; DOE 1988; Smith 1988), and a suprabasalt sediment sequence consisting of late Miocene to Holocene deposits (Figure 4) (Myers et al. 1979; Tallman et al. 1981; DOE 1988; Lindsey 1991a,b; Reidel et al. 1992).

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Figure 1. Location Map of the Pasco Basin and Hanford Site.

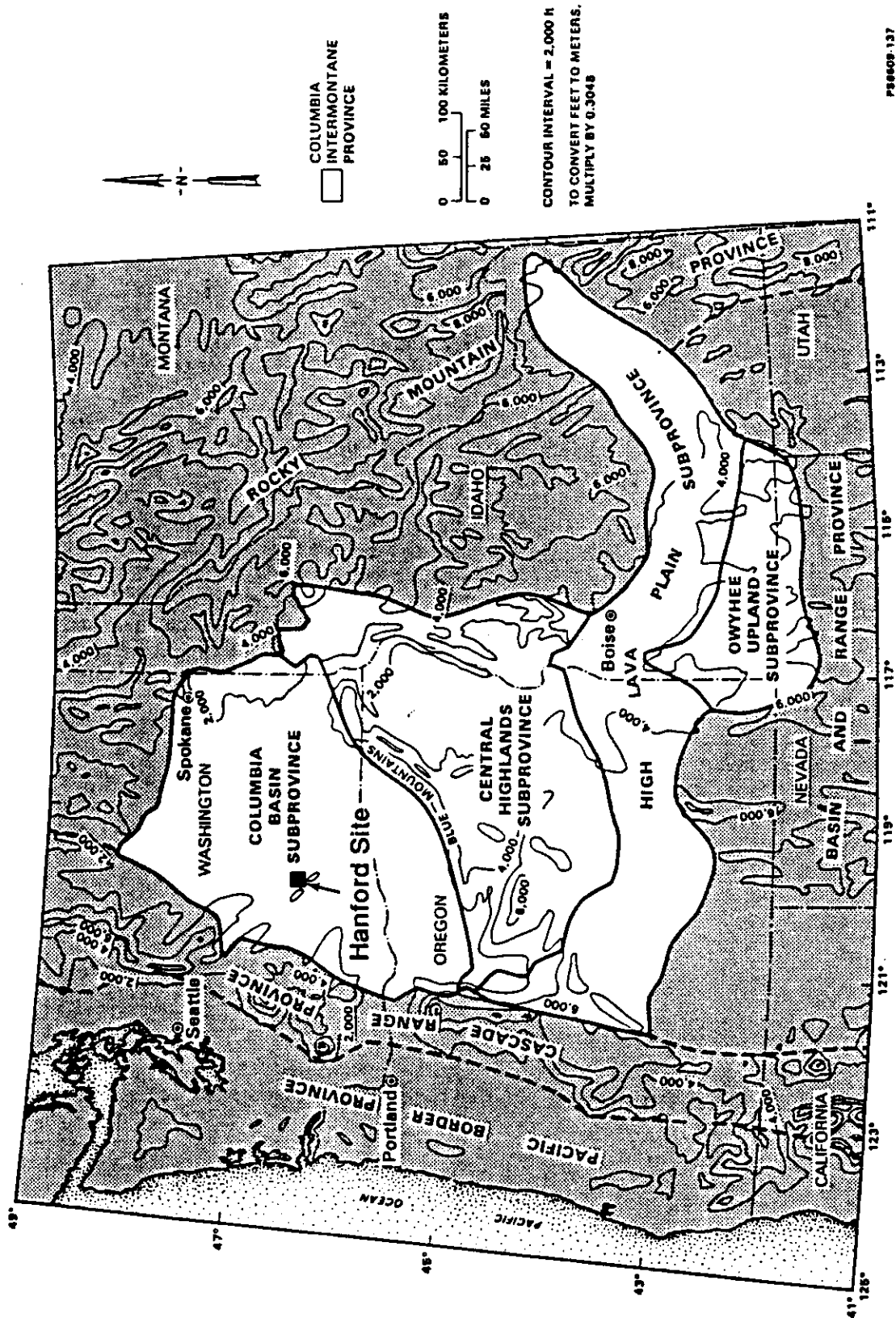


Figure 2. Divisions of the Columbia Intermontane Province and Adjacent Snake River Plains Province.

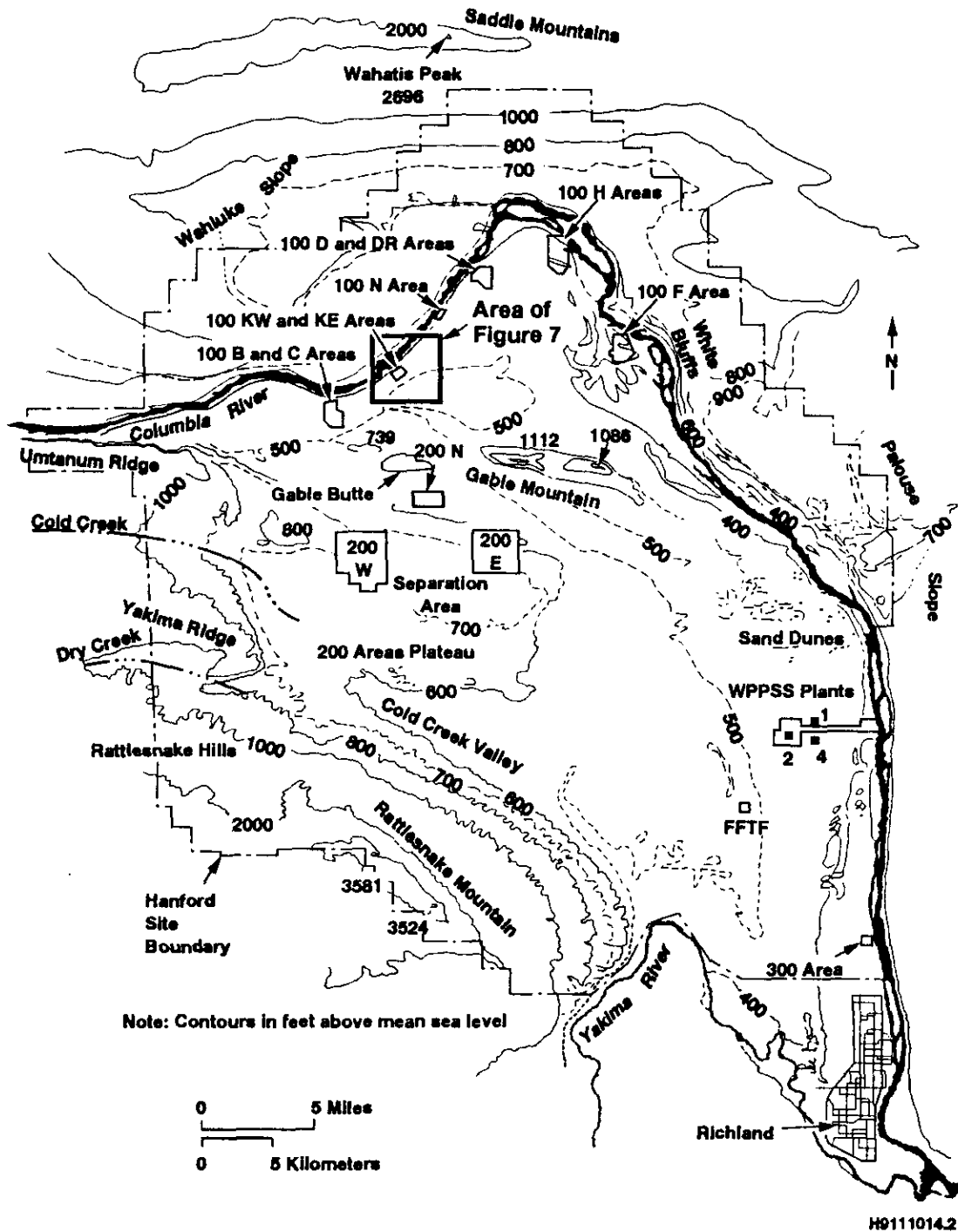


Figure 3. Topographic and Geographic Setting of the Hanford Site.

Period	Epoch	Group	Formation	Isotopic Age Dates Years x 10 ⁶	Member (Formal and Informal)	Sediment Stratigraphy or Basalt Flows
QUATERNARY	Holocene				Surficial Units	Loess
						Sand Dunes
						Alluvium and Alluvial Fans
						Landslides
TERTIARY	Pleistocene	Columbia River Basalt Group	Saddle Mountains Basalt		Hanford formation	Talus
						Colluvium
					Plio-Pleistocene/early Palouse/pre-Missoula interval	
					Ringold Formation	
TERTIARY	Miocene	Columbia River Basalt Group	Saddle Mountains Basalt		Ice Harbor Member	basalt of Goose Island
						basalt of Martindale
						basalt of Basin City
						Levey Interbed
						basalt of Ward Gap
						basalt of Elephant Mountain
						Rattlesnake Ridge Interbed
						basalt of Pomona
						Selah Interbed
						basalt of Gable Mountain
						Cold Creek Interbed
						basalt of Huntzinger
			Wanapum Basalt		Asotin Member	basalt of Lapwai
						basalt of Wahluke
						basalt of Sillust
						basalt of Umatilla
						Mabton Interbed
						basalt of Loio
						basalt of Rosalia
						Quincy Interbed
						basalt of Roza
						Squaw Creek Interbed
						basalt of Lyons Ferry
						basalt of Sentinel Gap
			Grande Ronde Basalt*		Frenchman Springs Member	basalt of Sand Hollow
						basalt of Silver Falls
						basalt of Ginkgo
						basalt of Palouse Falls
						Vantage Interbed
						basalt of Museum
						basalt of Rocky Coulee
						basalt of Levering
						basalt of Cohasset
						basalt of Birkett
						basalt of McCoy Canyon
						basalt of Umtanum
			Innate		American Bar Unit	basalt of Benson Ranch

*The Grande Ronde Basalt consists of at least 120 major basalt flows. Only a few flows have been named. N₂, R₂, N₁ and R₁ are magnetostratigraphic units.

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Figure 4. Generalized Stratigraphy of the Pasco Basin and Surrounding Area.

2.2.1 Columbia River Basalt Group

The Columbia River Basalt Group (Figure 4) is an assemblage of tholeiitic, continental flood basalts of Miocene age (DOE 1988; Reidel and Hooper, 1989). The basalts cover an area of more than 63,000 mi² (163,157 km²) in Washington, Oregon, and Idaho and have an estimated volume of about 40,800 mi³ (174,356 km³) (Tolan et al. 1989). Isotopic age determinations summarized in Reidel et al. (1989) indicate that basalt flows were erupted between approximately 17 to 6 Ma.

Columbia River Basalt flows were erupted from north-northwest-trending linear vent systems in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1979). The Columbia River Basalt Group is divided, from oldest to youngest, into five formations: Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt (DOE 1988; Reidel et al. 1989; Tolan et al. 1989). The Saddle Mountains Basalt (the uppermost basalt at the Hanford Site) is divided into several members. From oldest to youngest they are the Umatilla, Wilbur Creek, Asotin, Esquatzel, Pomona, Elephant Mountain, and Ice Harbor Members. Throughout the 100 Areas the Elephant Mountain Member is the uppermost basalt (DOE 1988).

2.2.2 Ellensburg Formation

The Ellensburg Formation consists of a mix of volcaniclastic and siliciclastic deposits that occur between the basalt flows of the Columbia River Basalt Group (Figure 4) (DOE 1988; Smith 1988). Stratigraphic nomenclature for the Ellensburg Formation is based on the basalt flows bounding the upper and lower surface of the sedimentary interbed and thus the names are valid only for those areas where the bounding basalt flows occur. Because most of the bounding flows occur in the Pasco Basin, the names given in Figure 4 are applicable to the Hanford Site. At Hanford the three uppermost units of the Ellensburg Formation are, from oldest to youngest, the Selah interbed, the Rattlesnake Ridge interbed, and the Levy interbed. The Rattlesnake Ridge interbed is the uppermost unit of the Ellensburg Formation in the 100 Areas. A detailed discussion of the Ellensburg Formation at the Hanford Site is given in Reidel and Fecht (1981). Smith (1988) and Smith et al. (1989) provide discussions of the Ellensburg and correlative units throughout the region.

2.2.3 Suprabasalt Sediments

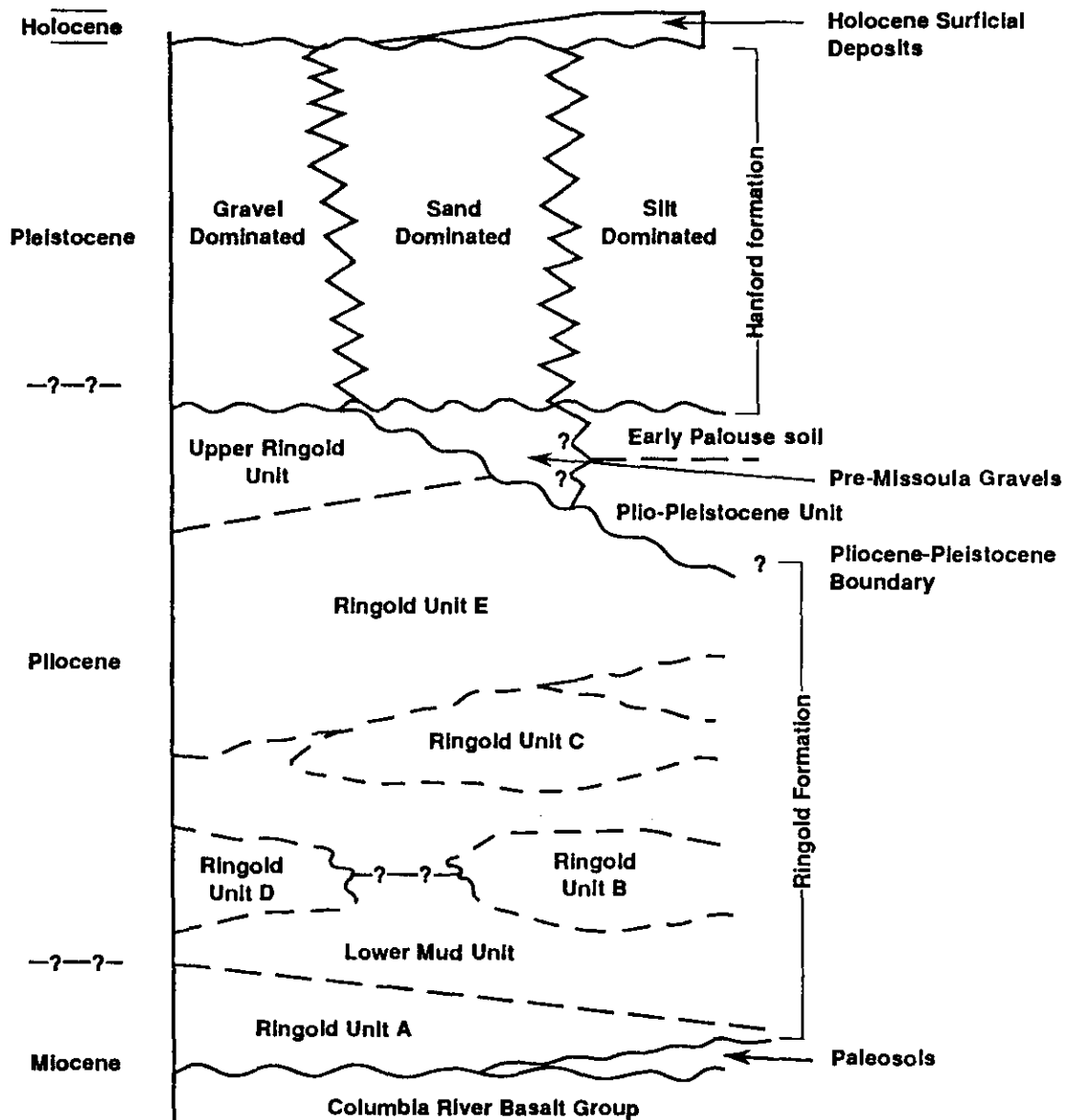
The general geologic features of the suprabasalt sediments at the Hanford Site are discussed in a number of reports. Discussions of various aspects of suprabasalt sediment geology are found in Myers et al. (1979), Tallman et al. (1979, 1981), PSPL (1982), Bjornstad (1984), Fecht et al. (1987), DOE (1988), Smith et al. (1989), Delaney et al. (1991), Lindsey (1991a, 1992), Lindsey et al. (1991, 1992) and Reidel et al. (1992). Delaney et al. (1991), Lindsey (1991a), and Reidel et al. (1992) provide the most recent synopsis of suprabasalt sediment geology for the Hanford Site.

Lindsey (1992) is the most recent synopsis of the suprabasalt geology for the 100 Areas. The following summary of these reports is from Lindsey and Jaeger (1993).

The suprabasalt sedimentary sequence is up to 750 ft (229 m) thick at the Hanford Site. This sequence is dominated by laterally extensive deposits assigned to the late Miocene to Pliocene Ringold Formation and the Pleistocene Hanford formation (Figures 4 and 5). Laterally discontinuous units referred to as the Plio-Pleistocene unit, early "Palouse" soil, and pre-Missoula gravels locally separate the Hanford formation and Ringold Formation (Figure 5). Laterally discontinuous Holocene-aged alluvial and eolian deposits cap the suprabasalt sequence.

2.2.3.1 Ringold Formation. The Ringold Formation is up to 600 ft (183 m) thick within the Pasco Basin. It pinches out against basalt ridges around the edge of and within the basin. The Ringold Formation consists of semi-indurated clay, silt, fine- to coarse-grained sand, and pebble to cobble gravel that are grouped into five sediment facies associations that are defined on the basis of these lithologies, petrology, stratification, and pedogenic alteration. The facies associations are:

- **Fluvial gravel**--This association consists of clast and lesser matrix supported pebble to cobble gravel with a fine- to medium-grained sand matrix. Grain size distributions tend to be bimodal with granules and coarse-grained sand being lower in abundance. Crude to well defined stratification and low angle, lenticular bedding geometries generally dominate. The association was deposited in a gravelly fluvial system characterized by wide, shallow, shifting channels.
- **Fluvial sand**--Fine- to coarse-grained quartzo-feldspathic sands displaying well defined stratification dominates this association. Fining upwards packages less than 1 m to several meters thick are common. The association records deposition in wide, shallow channels incised into muddy floodplains.
- **Overbank-Paleosol**--Laminated to massive silty sand, silt, and clay displaying variable amounts of evidence of pedogenic alteration dominates the association. These sediments record deposition under floodplain conditions and the formation of paleosols.
- **Lacustrine**--Generally well stratified clay with interbedded silt and silty sand characterizes this association. These sediments were deposited in a lake under standing water to deltaic conditions.
- **Basaltic alluvium**--Massive to crudely stratified, weathered to unweathered, basaltic, pebble to cobble gravel dominates this association. These gravels commonly have a mud-rich matrix and are inferred to have been deposited in ephemeral streams and by debris flows in alluvial fan settings.



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Figure 5. Generalized Stratigraphy of the Suprabasalt Sediments Surrounding Area.

The distribution of facies associations within the Ringold Formation forms the basis for stratigraphic subdivision (Lindsey 1991a). Three subdivisions or stratigraphic packages are recognized (Lindsey 1991b; Reidel et al. 1992). The first of these forms the lower half of the Ringold Formation and is characterized by intervals dominated by fluvial gravels and sands, designated units A, B, C, D, and E (Figure 5), that interfinger with intervals containing fine-grained deposits typical of the overbank-paleosol and lacustrine facies associations. The lowest of these fine-grained intervals is designated the lower mud unit (Figure 5). Interstratified deposits typical of the fluvial sand and overbank-paleosol facies associations dominate the second package. The third and uppermost package is dominated by the lacustrine facies association.

2.2.3.2 Post-Ringold and Pre-Hanford Units. Three informal units separate the Ringold Formation from the Hanford formation in various parts of the Hanford Site. These units are the: (1) Plio-Pleistocene unit, (2) Pre-Missoula gravels, and (3) Early "Palouse" soil (Figure 4) (Myers et al. 1979; Tallman et al. 1979, 1981; DOE 1988; Reidel et al. 1992). None of these units are found in the 100 Areas.

2.2.3.3 Hanford Formation. The Hanford formation consists of pebble to boulder gravel, fine- to coarse-grained sand, and silt deposited by cataclysmic flood waters that drained out of glacial lake Missoula (Fecht et al. 1987; DOE 1988; Baker et al. 1991). The Hanford formation is thickest in the vicinity of 200 West and 200 East areas where it is up to 215 ft (66 m) thick. Hanford formation deposits are absent on ridges above approximately 1,200 ft (366 m) above sea level, the highest level of cataclysmic flooding in the Pasco Basin. The Hanford formation is divided into three facies: (1) gravel-dominated, (2) sand-dominated, and (3) silt-dominated. It is important to note that these facies are end members within a continuum of sediment types where sharp distinctions cannot always be made. The Hanford formation facies also are referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies (Baker et al. 1991).

- Gravel-dominated facies--This facies generally consists of coarse-grained basaltic sand and granule to boulder gravel that display massive bedding, plane to low-angle bedding, and large-scale planar cross-bedding in outcrop. These gravels commonly are uncemented and matrix-poor, displaying an open-framework texture. Lenticular sand and silt beds can be intercalated in the facies. While the facies generally is basaltic, quartzo-feldspathic lithologies also are present. The gravel-dominated facies was deposited by high-energy flood waters in or immediately adjacent to main cataclysmic flood channelways.
- Sand-dominated facies--This facies consists of well stratified, fine- to coarse-grained sand and granule gravel. The silt content of the facies is variable, but where it is low a well sorted and open framework texture is common. The sand-dominated facies may contain small pebbles and rip-up clasts in addition to pebble-gravel interbeds and silty interbeds less than 1 m thick. These interbedded lithologies generally are lenticular although laterally continuous horizons are present. The laminated sand facies was deposited during the waning stages of flooding and as water spilled

out of channelways, loosing competence. This facies is transitional between the gravel-dominated and silt-dominated facies.

- Silt-dominated facies--Interstratified silt and fine- to coarse-grained sand dominates this facies. Normally graded rhythmites a few centimeters to several tens of centimeters thick containing planar lamination and ripple cross-lamination is characteristic of the facies. The facies records deposition under slackwater conditions and in back flooded areas (DOE 1988).

In addition to the three Hanford formation facies outlined above, clastic dikes also are commonly found in the Hanford formation as well as locally in other sedimentary units in the Pasco Basin (Black 1979). Clastic dikes, whether in the Hanford formation or other sedimentary units, are structures that generally cross-cut bedding, although they do locally parallel the bedding. The dikes usually consist of alternating vertical to subvertical layers (millimeters to centimeters thick) of silt, sand, and granules. Where the dikes intersect the ground surface a feature known as patterned ground can be observed.

2.2.3.4 Holocene Surficial Deposits. Holocene surficial deposits consist of silt, sand, and gravel that form a thin veneer (<16 ft [4.9 m]) across much of the Hanford Site. These sediments were deposited by a mix of eolian and alluvial processes.

2.2.4 Structural Geology

The Columbia Plateau is divided into three informal structural subprovinces: Blue Mountains, Palouse, and Yakima Fold Belt (Tolan and Reidel 1989). These structural subprovinces are delineated on the basis of their structural fabric, unlike the physiographic provinces that are defined on the basis of landforms. The Hanford Site is located in the eastern Yakima Fold Belt near its junction with the Palouse subprovince.

The Yakima Fold Belt consists of a series of segmented, narrow, asymmetric, and generally east-west trending anticlines (Reidel et al. 1989). The northern limbs of these anticlines generally dip steeply to the north or are vertical. The south-dipping limbs generally dip at relatively shallow angles. Thrust or high-angle reverse faults with fault planes that strike parallel to the anticline axial trends are principally found on the north sides of these anticlines. The anticlinal ridges are separated by broad synclines or basins that may contain accumulations of Neogene- to Quaternary-age sediments. Deformation of the Yakima folds occurred under north-south compression and pre-dates (was contemporaneous with) and post-dates the eruption of the Columbia River basalts (Reidel 1984; Reidel et al. 1989, 1992).

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The Pasco Basin (where the Hanford Site is situated) is one of the largest structural basins within the Yakima Fold Belt. The Pasco Basin is bounded on the north by the Saddle Mountains anticline, on the west by the Hog Ranch-Naneum Ridge anticline, and on the south by the Rattlesnake Mountain anticline (Figure 6). The Palouse slope, a west-dipping monocline, bounds the Pasco Basin on the east (Figure 6). The Pasco Basin is divided into the Wahluke and Cold Creek synclines by the Gable Mountain anticline, the easternmost extension of the Umtanum Ridge anticline (Figure 6).

The Wahluke syncline (Figure 6) is the principal structure that contains the 100 Areas. The Wahluke syncline is asymmetric and relatively flat-bottomed with a gently-dipping north limb (approximately 5°) and a steeply-dipping south limb.

3.0 GEOLOGY OF THE 100-K AREA

The 100-K Area and vicinity (Figures 3 and 7) is underlain (from oldest to youngest) by flows of the Columbia River Basalt Group with intercalated Ellensburg Formation, the Ringold Formation, the Hanford formation, and scattered Holocene deposits. The study area is situated near the axis of the asymmetrical Wahluke sycline. South of the study area, basalt flows and the older units of the Ringold Formation dip steeply to the north. North of the study area, those same strata dip at shallow angles to the south.

Geologic interpretations in this report are based on geologic logs from 26 boreholes; 15 boreholes are located within the study area, and 11 boreholes are surrounding the study area (Figure 7). A majority of the boreholes (19) reach only slightly below the water table, but six wells go into the lower portions of the aquifer and one encounters basalt. Geologic information derived from the 26 boreholes was used to construct five geologic cross sections in the study area (Figures 8 through 12). Two of the cross sections run southwest-northeast (A-A' and B-B', Figures 8 and 9), and three are nearly perpendicular to the first two (C-C', D-D', and E-E', Figures 10, 11, and 12). Locations of the cross sections are shown in Figure 7. Cross sections C-C', D-D', and E-E' extend to the northwest and show the relationship of the stratigraphy and water table to the Columbia River.

3.1 COLUMBIA RIVER BASALT GROUP

Only one borehole in the study area encounters basalt (6-81-62, Figure 7). Basalt is encountered at a depth of approximately 527 ft (161 m) (cross section E-E', Figure 12). As throughout the 100 Areas, the first basalt member encountered in the 100-K Area is the Elephant Mountain Member of the Saddle Mountains Basalt (Section 2.2.1 and DOE 1988).

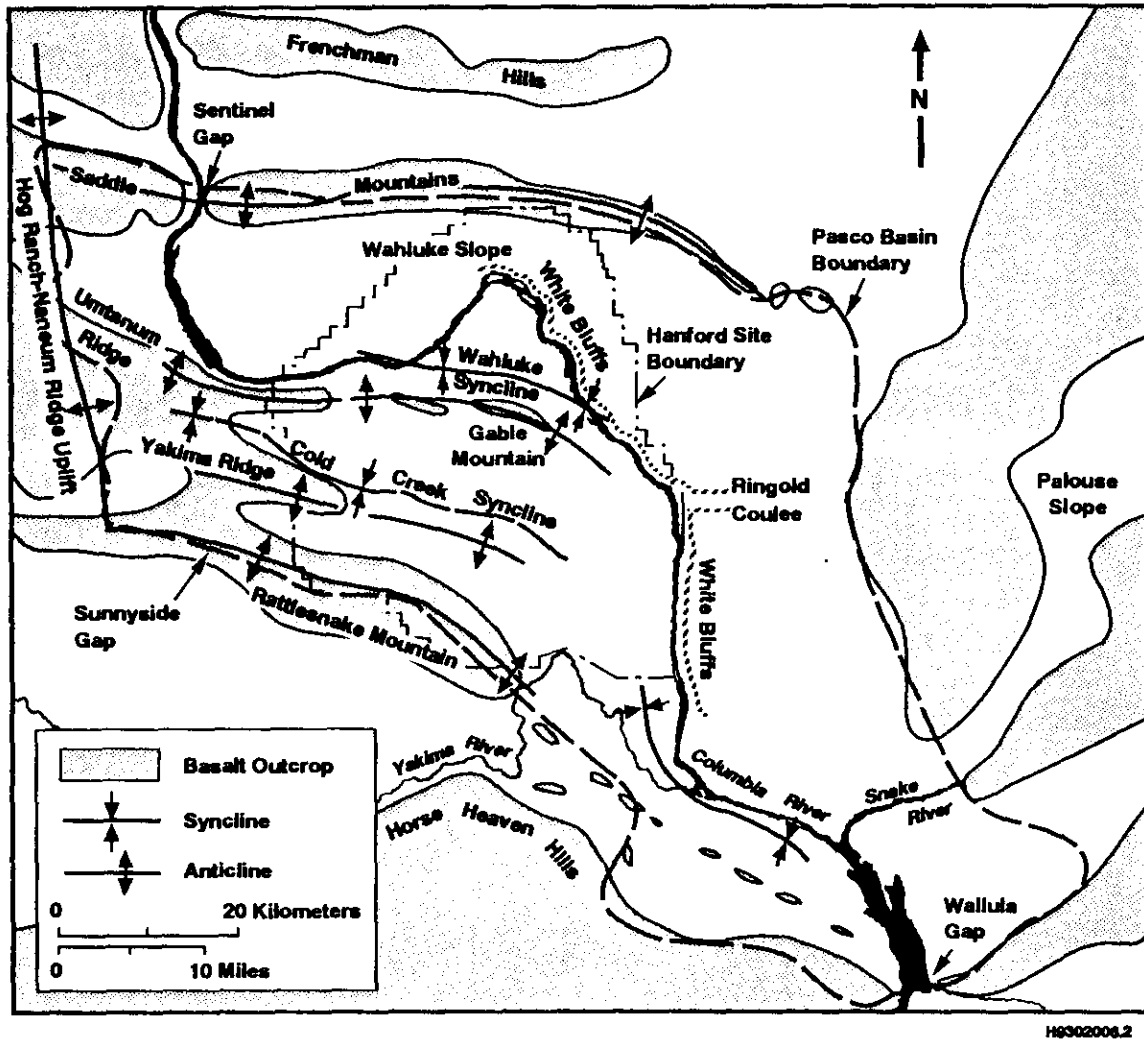


Figure 6. Generalized Structure of the Pasco Basin.

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Figure 7. Locations of Wells and Geologic Cross Section in the 100-K Area and Vicinity.

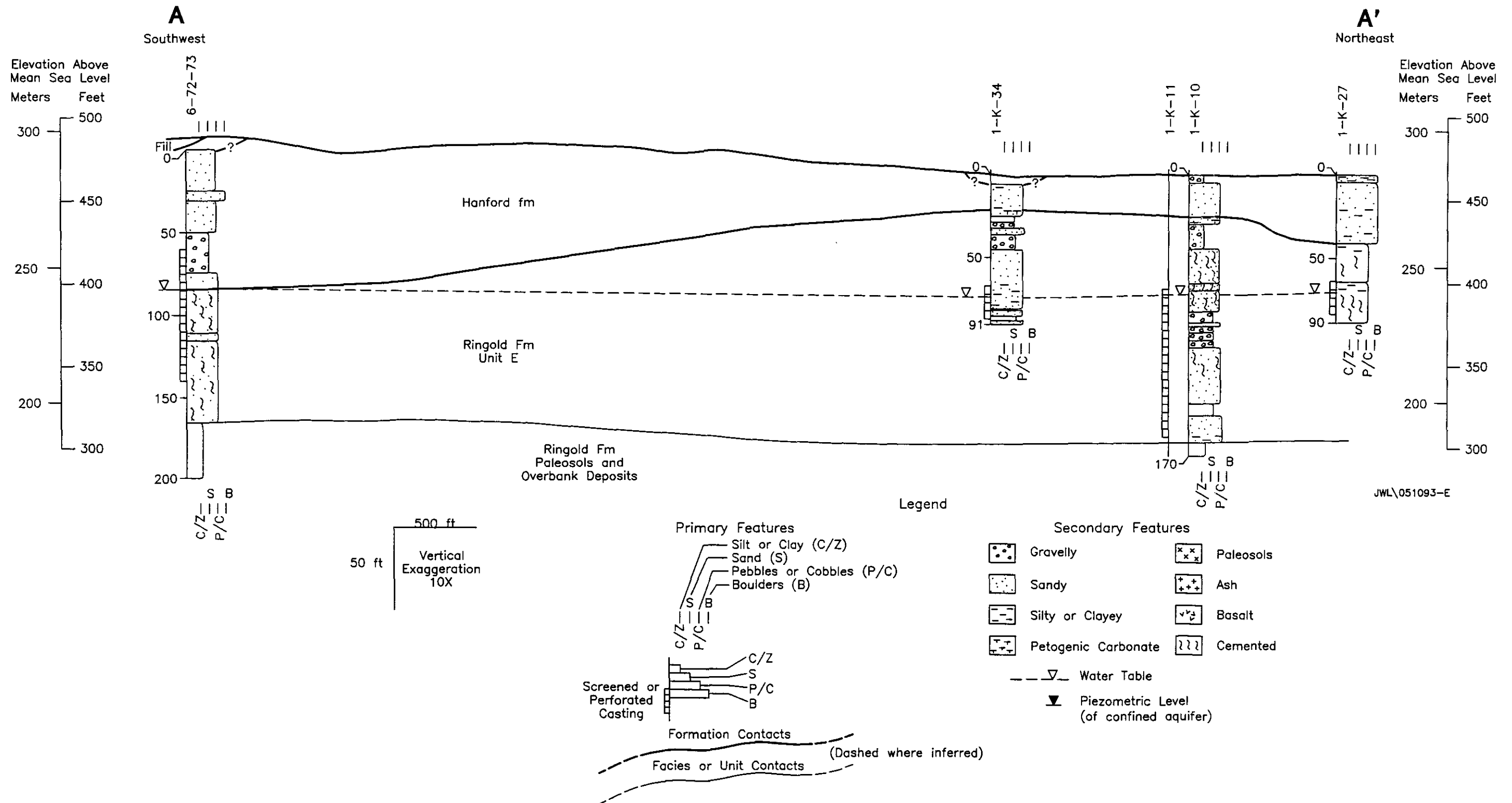


Figure 8. Geologic Cross Section A-A'.

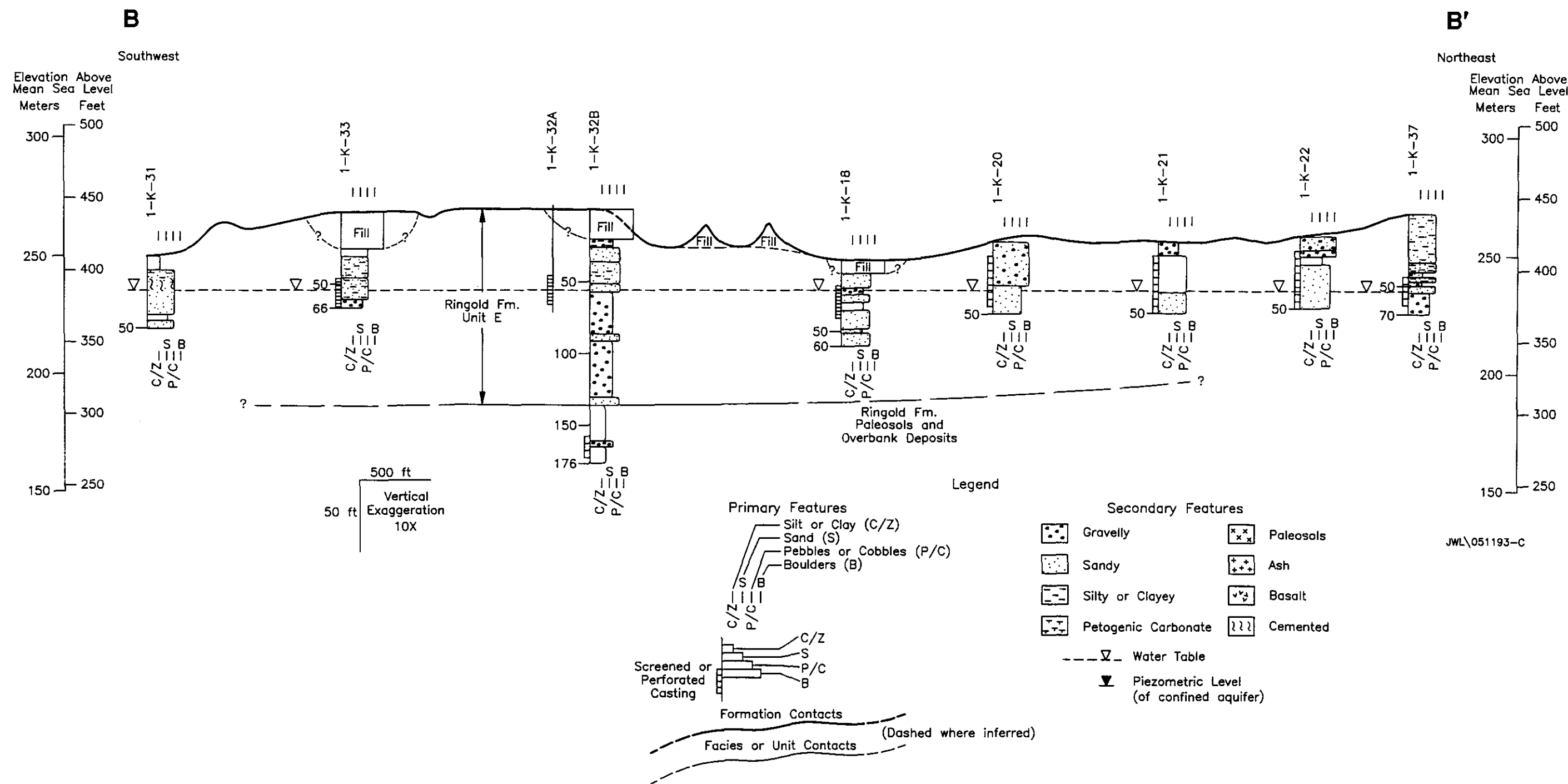


Figure 9. Geologic Cross Section B-B'.

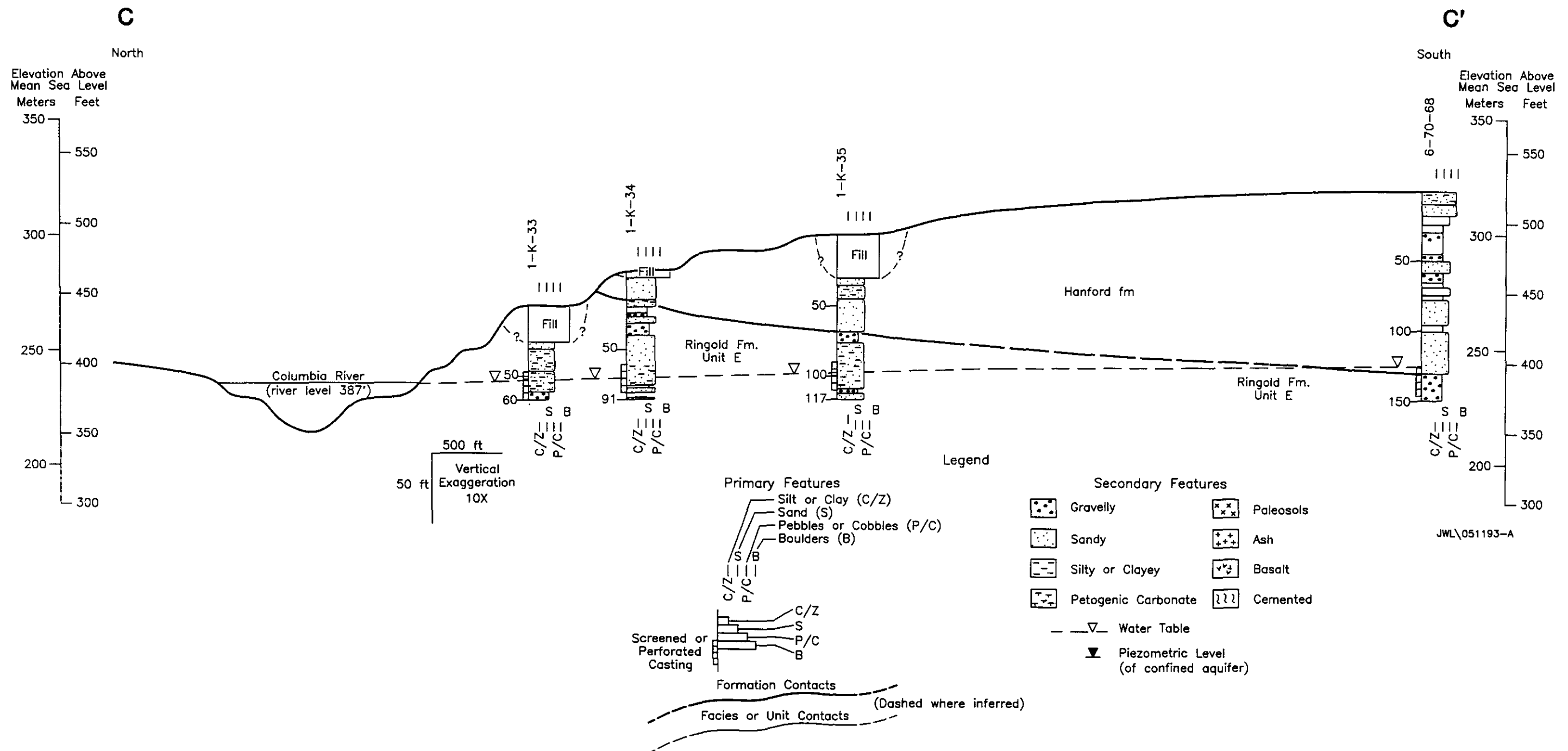


Figure 10. Geologic Cross Section C-C'.

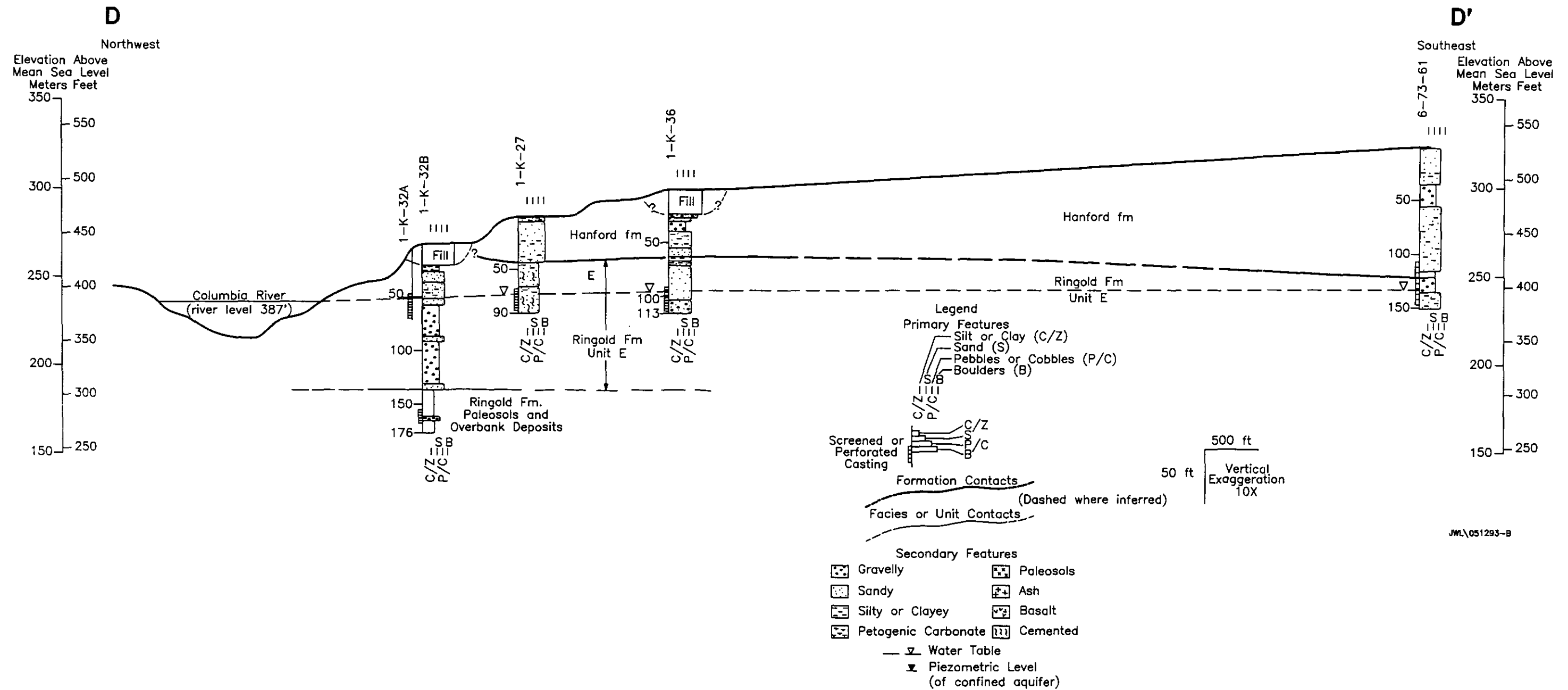


Figure 11. Geologic Cross Section D-D'.

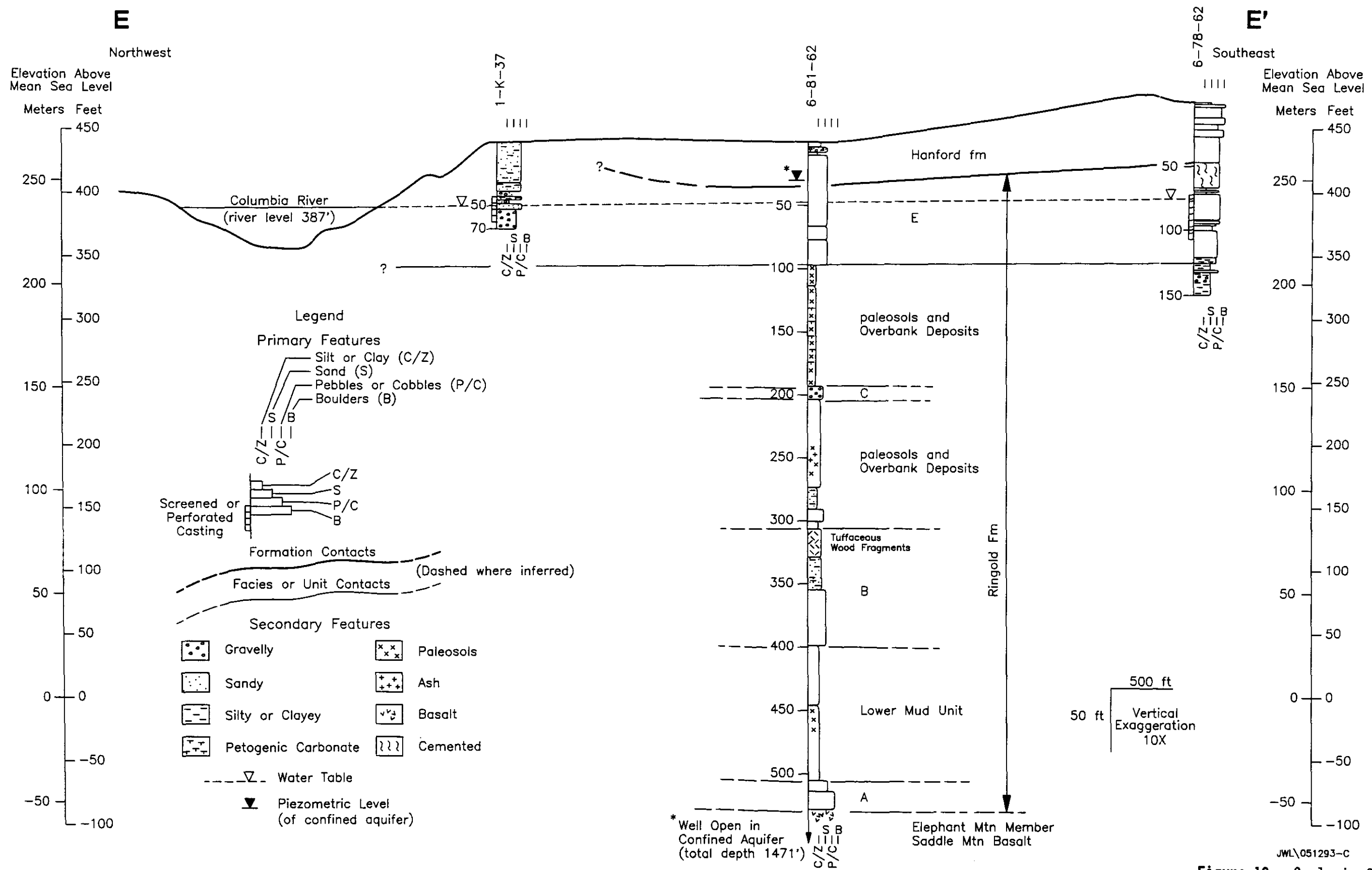


Figure 12. Geologic Cross Section E-E'.

3.2 RINGOLD FORMATION

The Ringold Formation beneath the study area contains most of the Ringold units commonly encountered elsewhere at the Hanford Site. The fluvial gravel and sand units A, B, C, and E (in ascending order) are present and intercalated with lacustrine and fluvial overbank deposits and paleosols (Lindsey 1992). Unit D is probably not in the study area. All of these units (except for D) are penetrated in borehole 6-81-62 (northeastern portion of the study area, Figure 7). In borehole 6-81-62 the Ringold Formation has a total thickness of approximately 493 ft (150 m). Most of the following discussion about the stratigraphy beneath unit E of the Ringold Formation is derived from borehole 6-81-62 (cross section E-E', Figure 12). Other boreholes are not deep enough. The following sections are descriptions of individual units within the Ringold Formation (lower to upper).

3.2.1 Unit A

Unit A, the lowermost unit within the Ringold Formation, is approximately 23 ft (7 m) thick and consists of fluvial gravel facies grading upward into sand associations. The sand fraction is quartz rich, giving it a tan color. Unit A most likely overlies basalt throughout the study area.

3.2.2 Lower Mud Unit

Overlying unit A is the lower mud unit of the Ringold Formation. The lower mud unit is approximately 105 ft (32 m) thick and consists predominantly of blue-grey to black, locally micaceous, lacustrine muds, and brown to green fluvial overbank deposits. The middle 20 to 30 ft (6 to 9 m) of the unit contains pedogenic calcium carbonate and displays a characteristic hackly fracture pattern typical of bioturbation and subaerial exposure. This indicates the presence of paleosols.

3.2.3 Unit B

Unit B is approximately 92 ft (28 m) thick and consists predominantly of sand. The lower portion of the unit is a cross-bedded sand that is medium grained, quartzose, and sometimes micaceous. It grades upward into a silty sand that is tan to grey-brown, tuffaceous in places, and contains wood fragments.

3.2.4 Unit C and Associated Paleosols and Overbank Deposits

Overlying unit B is a 209 ft (64 m) thick sequence of predominantly muds and sandy muds typically displaying characteristics of paleosols and fluvial overbank deposits. The sequence has three parts; an upper and a lower part that are predominantly silt to sandy silt, and a middle section of gravelly sand.

The lower 103 ft (31 m) of mud is predominantly silt and sandy silt. Starting from the base of this unit is 6 to 7 ft (2 m) of olive brown silt followed by 9 ft (3 m) micaceous silty sand, 17 ft (5 m) of tan iron-stained silt, and 70 ft (21 m) of brown sandy silt. The brown sandy silt displays the hackly fracturing, pedogenic carbonate, massive bedding, and color typical of paleosols. It also has a thin tuffaceous layer near the middle of its thickness.

The middle gravelly portion is approximately 10 ft (3 m) thick and is composed predominantly of gravelly sand that may be correlatable to the 113 ft (34 m) of fluvial sandy gravels of unit C in the 100-B/C Area (Lindberg 1993).

The 96 ft (29 m) of mud at the top of the sequence is also predominantly silt. The color ranges from tan to grey-brown to olive brown. Throughout most of its thickness, the silt contains pedogenic carbonate and other characteristics that suggest paleosols.

3.2.5 Unit E

The uppermost unit of the Ringold Formation within the study area is the coarse-grained unit E which is predominantly composed of the fluvial gravel and fluvial sand facies (Section 2.2.3.1). It is fully penetrated by six boreholes in the study area. The boreholes are (from southwest to northeast): 6-72-73, 1-K-10, 1-K-11 (near 1-K-10 and showing an almost identical stratigraphic section), 1-K-32b, 6-78-72, and 6-81-62 (Figure 7). With the exception of borehole 1-K-11, the geologic logs of these boreholes are shown on cross sections A-A', B-B', D-D', and E-E' (Figures 8, 9, 11, and 12). A contour map of the base of unit E (or the top of the next lower unit) and a isopach map of unit E are not provided because the nearly linear arrangement of the boreholes makes it very difficult to construct these maps.

The base of unit E, from what can be interpreted from the six wells reaching the base, is a fairly flat surface with a relief of only about 40 ft (12 m). The lowest known point on the base is at borehole 1-K-10 (303 ft or 92 m elevation) and the highest is at borehole 6-78-62 (344 ft or 105 m elevation).

Known thickness of unit E ranges from 64 ft (20 m) at borehole 6-81-62 to 136 ft (41 m) at borehole 1-K-10. However, the unit may actually be thicker in the area between cross sections A-A' and B-B' where there is no stratigraphic control. In this area between cross sections A-A' and B-B', the base of unit E is relatively flat, but the upper surface is rising with proximity to the Columbia River (cross section C-C', Figure 10). The upper surface of unit E (i.e., the upper surface of the Ringold Formation) will be discussed further in Section 3.4.

3.3 HANFORD FORMATION

The Hanford formation in the study area is a wedge that decreases in thickness toward the Columbia River. In the area of boreholes 6-73-61 and 6-70-68 (south and southeast) the formation is approximately 120 to 130 ft

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(37 to 40 m) thick. In contrast, along the Columbia River between cross sections A-A' and B-B' (Figures 8 and 9) the Hanford formation pinches out. The reduction in thickness appears to be quite uniform from southeast to northwest across the study area (Figure 13). Isopleth lines of formation thickness are parallel to, and consistent with, the trend of Hanford formation isopach lines in the 100-B/C Area (Lindberg 1993).

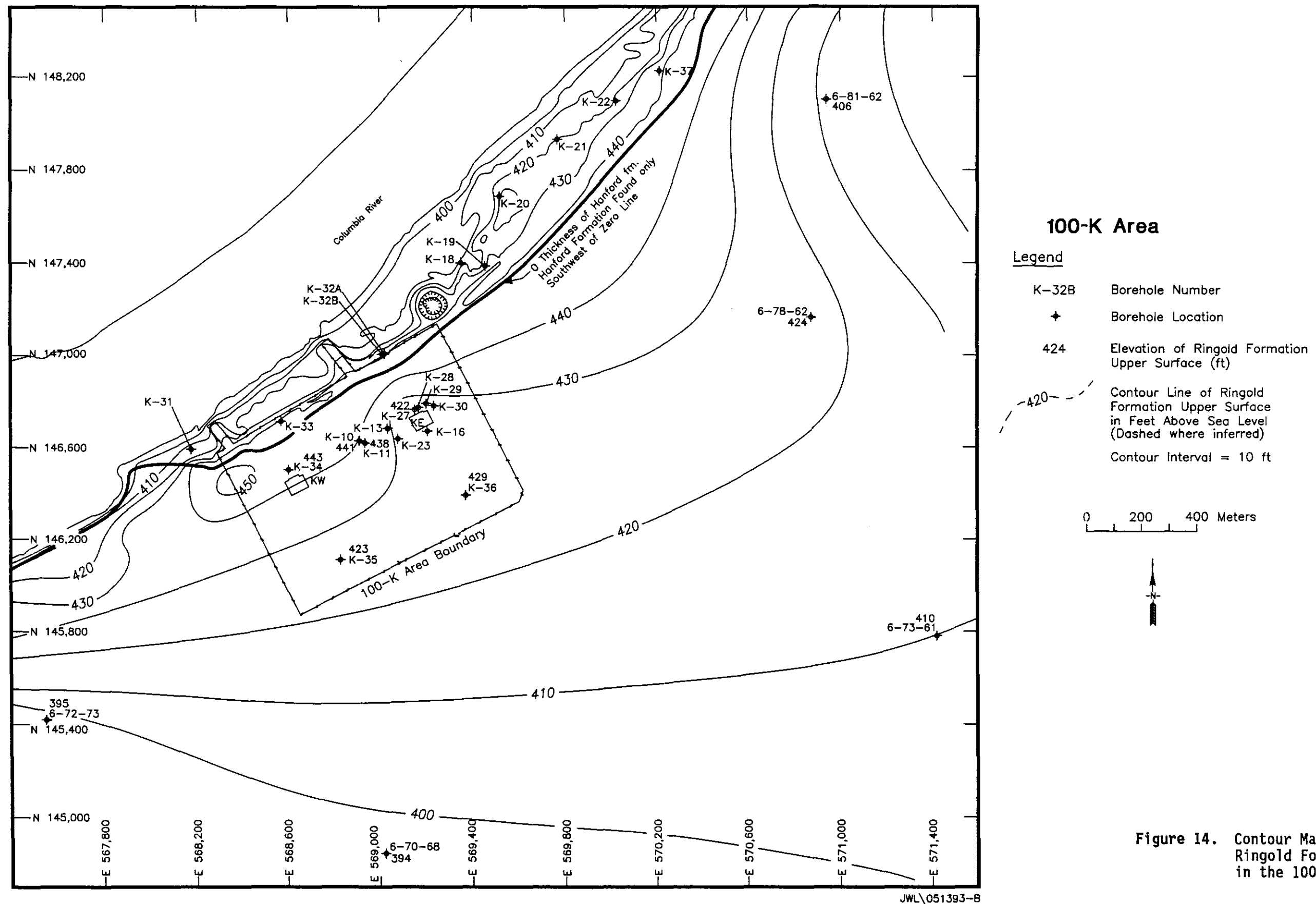
The gravel-dominated facies predominates in the Hanford formation throughout the study area. The sand-dominated facies occurs locally in a few intervals, but is not thick or extensive enough to correlate from borehole to borehole. Significant silt-dominated facies is not apparent. Boulder gravel is often found in the upper 20 to 50 ft (6 to 15 m) of the Hanford formation causing difficult drilling conditions shortly after spudding in.

3.4 HANFORD FORMATION/RINGOLD FORMATION CONTACT

The boreholes along cross section B-B' do not encounter the Hanford formation, but enter the Ringold Formation near the ground surface. The remainder of the boreholes in the study area not only encounter the Hanford formation, but fully penetrate it and at least encounter unit E of the Ringold Formation. The contour map of the upper surface of the Ringold Formation (Figure 14) shows that the surface is inclined and rises to the north and west with the highest elevations near the pinchout of the Hanford formation (cross section C-C', Figure 10). Along the Columbia River the upper surface of the Ringold Formation is exposed and slopes down to the present river channel (Figures 10, 11, and 12).

The 100-K Area is geologically different than surrounding areas (100-B/C and 100-N areas) because the Ringold Formation is exposed, not only along the banks of the Columbia River, but also from the river to 1,200 ft (366 m) or more away from the river to the southeast. (See the zero thickness line on Figures 13 and 14). At the 100-B/C Area the Ringold Formation is probably exposed in the channel of the Columbia River (areas below approximately 400 ft [122 m] in elevation), but the Hanford formation covers the Ringold Formation elsewhere (Myers et al. 1979; Lindberg 1993). Elevation of the ground surface is not significantly different, although overall, is slightly higher at the 100-B/C Area. The main difference in the two areas appears to be in the thickness of Ringold Formation unit E. At the 100-B/C Area, the base of unit E is between 300 and 350 ft (91 to 107 m) of elevation, and the top is around 400 ft (122 m). In the 100-K Area the base of unit E is also around 300 to 350 ft (91 to 107 m) of elevation, but the top is as high as 450 ft (137 m) (cross section C-C', Figure 10). As shown in Figure 14 the upper surface of the Ringold Formation is a sloping surface that rises to the northwest where unit E is thickest.

In the vicinity of the 100-K Area, unit E may be more cemented, and therefore, more resistant and possibly less eroded by Pleistocene cataclysmic floodwaters than unit E in surrounding areas. Attesting to the greater cementation in unit E locally is Coyote Rapids, which is located immediately upstream (west) of the 100-K Area. The development of rapids in the area immediately upstream of 100-K Area may be a response to the greater resistance of the unit E to the erosive power of the Columbia River.



3.5 HOLOCENE DEPOSITS

Holocene deposits in the study area are dominated by Columbia River deposits and eolian deposits. The river deposits consist of gravels and coarse-grained sands deposited in channels and silts and fine sands deposited in overbank area. Eolian deposits consist dominantly of less than 3 ft (0.9 m) of silty fine-grained sands that blanket much of the area except in locations where they were removed for construction purposes. In many locations eolian deposits are areally only a thin blanket (<1 ft or <0.3 m).

3.6 BACKFILL

Within the 100-K Area many excavations were made for the buildings and facilities, and most of these excavations were backfilled to some extent with local soils (usually sandy gravel of the Hanford formation or unit E of the Ringold Formation). Some of the boreholes that were drilled in the study area were located within these backfilled excavations. The boreholes encountering backfill as noted by the driller (or well-site geologist in more recently drilled boreholes) are as follows:

- | | |
|-----------|------------|
| • 1-K-18 | • 1-K-34 |
| • 1-K-32a | • 1-K-35 |
| • 1-K-32b | • 1-K-36 |
| • 1-K-33 | • 6-72-73. |

Backfill is also noted on the cross sections (Figures 8 through 12). However, the excavations containing the backfill are shown schematically because actual dimensions were unknown at the time the cross sections were made. Other boreholes also may have encountered backfill but not necessarily recognized by the driller (e.g., 1-K-27 is near or within an excavation but backfill was not recorded by the driller).

3.7 HYDROGEOLOGY

Figures 8 through 12 show the screened (or perforated casing) interval on each borehole. They also show the water table and level of the Columbia River on December 21, 1992. From these figures the water table can be interpreted as sloping gently from the southeast to the northwest where it encounters the Columbia River at about 387 ft (118 m) of elevation (December 21, 1992).

The vadose zone beneath the study area includes backfill in limited areas, Holocene surficial deposits, the Hanford formation (southeast of the zero thickness line, Figures 13 and 14), and the uppermost part of the Ringold Formation (unit E) (Figure 15). The vadose zone varies from zero thickness along the shore of the Columbia River to over 150 ft (46 m) in the southeastern portion of the study area. Most the vadose zone lies within the gravel-dominated facies of the Hanford formation (where the Hanford formation exists) and the upper part of Ringold Formation unit E (predominantly a fluvial gravel).

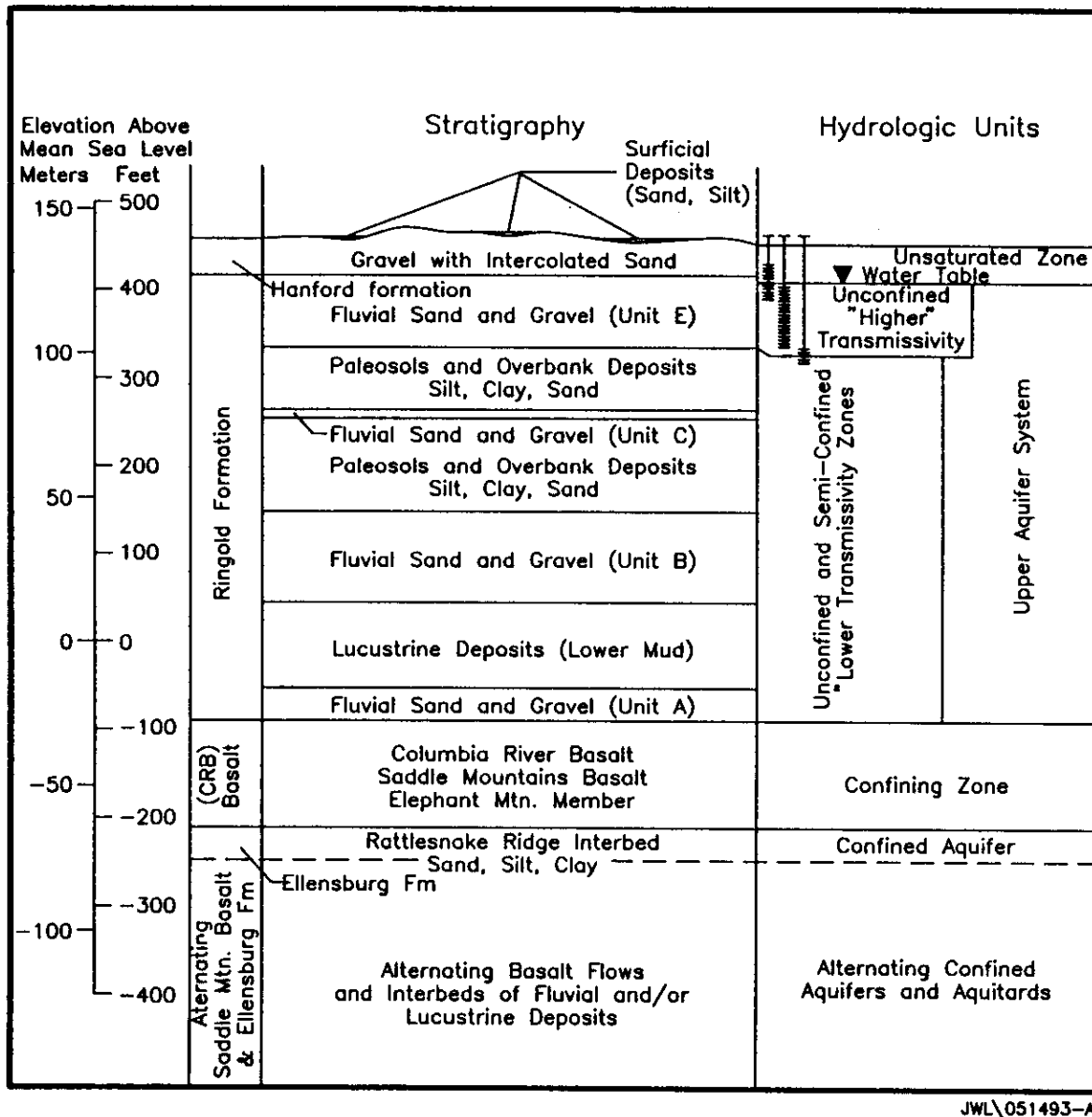


Figure 15. Comparison of Geologic and Hydrologic Units in the 100-K Area.

The "uppermost aquifer system" (Delaney et al. 1991) is found within the Ringold Formation and includes a series of confining and water producing zones. The upper part of the "uppermost aquifer system" is an unconfined zone of higher transmissivity and is within unit E of the Ringold Formation and within the lowest part of the Hanford formation in the extreme southern part of the study area (Figure 10, borehole 6-70-68). Below unit E, the "upper aquifer system" is unconfined or semiconfined, has lower transmissivity zones, and lies within alternating layers of coarse and fine Ringold Formation sediments (i.e., fluvial gravels and sands, and paleosols or overbank deposits). The "uppermost aquifer system" is underlain by the various Columbia River Basalt Group aquifers, which consist of alternating confining zones and confined aquifers. These alternating confining zones and confined aquifers correspond with alternating basalt flow interiors and more transmissive zones associated with flow-tops, rubbly and scoriaceous zones, or sedimentary interbeds.

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